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SEMI-ANNUAL STATUS REPORT NO. 8 ON SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES

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SEMI-ANNUAL STATUS REPORT NO. 5 TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

"SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES"

NAME AND ADDRESS OF INSTITUTION: GEORGETOWN UNIVERSITY
WASHINGTON, D. C. 20007

PROJECT DIRECTOR: Dr. Francis J. Heyden, S. J.

ASSISTANT SCIENTIFIC DIRECTOR: Dr. Carl C. Kiess

PROJECT HEAD: Dr. Whiting R. Willauer

Work Performed. During the last six months our observational data has been minimal since we have been engaged in mounting, modifying, and testing various pieces of equipment.

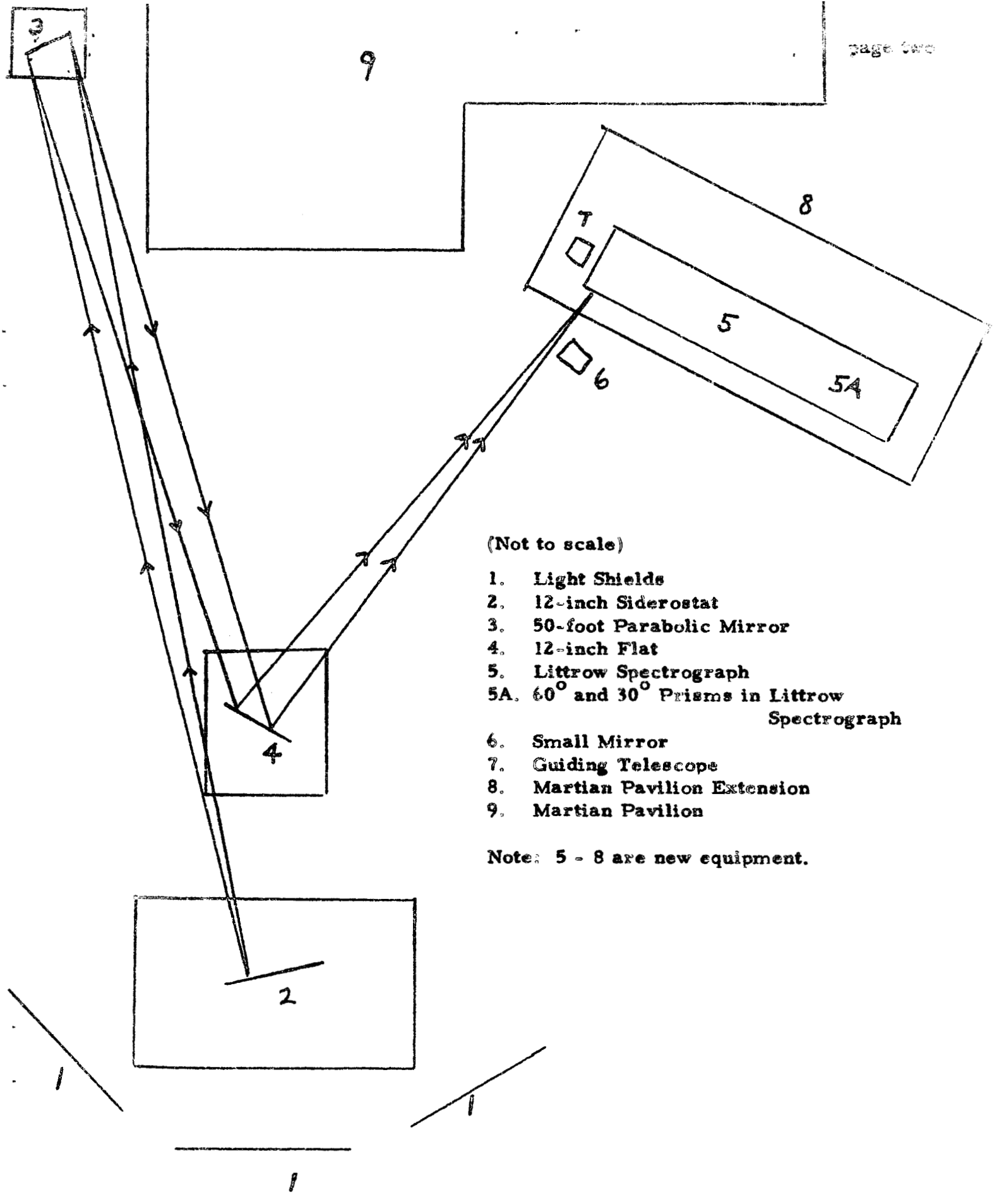
Our work includes the following areas:

1. Mounting, focusing, and testing the large Littrow spectrograph described in Semi-Annual Status Report No. 7
2. Testing a new "high speed" emulsion
3. Remounting the photoelectric scanner
4. Modifying our vacuum equipment
5. Other related studies.

Area 1. Mounting and Testing the Littrow Spectrograph.

After an examination of the floor space in the spectrograph shelter known as the Martian Pavilion and the location of the 12-inch siderostat, we decided to mount the large Littrow Spectrograph (described in Semi-Annual Status Report No. 7) in a new structure extending to the west of the pavilion. An old 24-foot trailer, hereafter referred to as the Martian Pavilion Extension, proved to be the least expensive and most readily available structure in which to house the spectrograph (Figure 1).

In order to mount the spectrograph, two concrete piers were



(Not to scale)

1. Light Shields
2. 12-inch Siderostat
3. 50-foot Parabolic Mirror
4. 12-inch Flat
5. Littrow Spectrograph
5A. 60° and 30° Prisms in Littrow Spectrograph
6. Small Mirror
7. Guiding Telescope
8. Martian Pavilion Extension
9. Martian Pavilion

Note: 5 - 8 are new equipment.

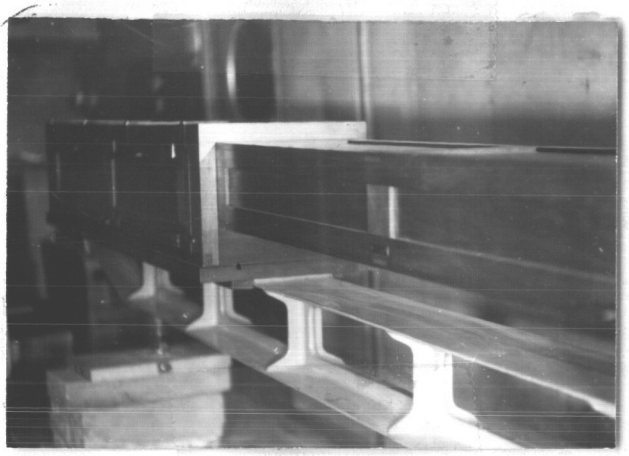
Diagram of the present Siderostat - Spectrograph Arrangement
Figure 1

constructed in this new shelter, then the Littrow was lifted onto the piers, leveled by means of small jacks, and aligned with the siderostat and the 50-foot focal length mirror network. Three operations were required in order to focus the instrument: 1. the prism train had to be rotated about a vertical axis until the proper spectral region was obtained 2. the prism train and quartz lens were moved horizontally until the center of the plate was focused and 3. the plate holder was rotated about a vertical axis until the ends of the plate were properly focused (Figure 2).

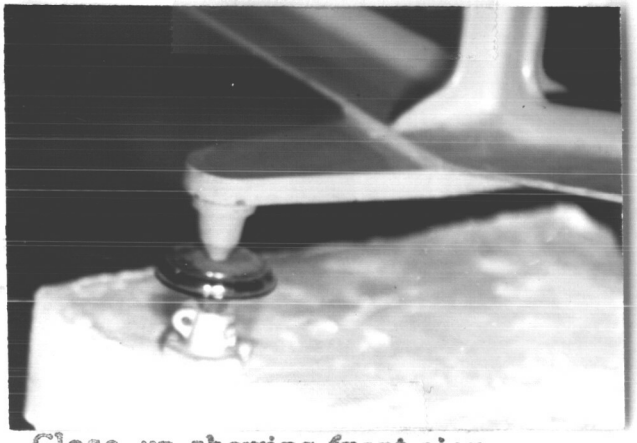
Test exposures taken with the moon show that the Littrow is faster than any of our gratings used with the Wadsworth Spectrograph. The prism instrument, since it concentrates all its light into one order, requires less time to form a photographic image.

These tests also indicate that the fifty-foot focal length mirror should be used in conjunction with this prism spectrograph. Even though the Littrow has an astigmatic slit, light is still lost by vertical image trailing.

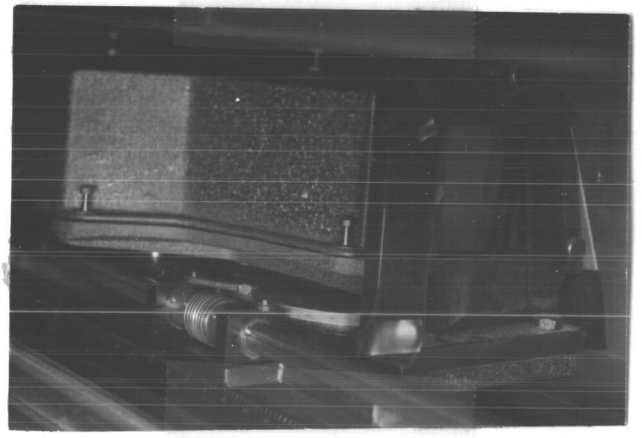
The experimentally determined dispersion curve for the Littrow (Figure 3) reveals its change in dispersion with changing wavelength -- a characteristic of all prism spectrographs. Several of our gratings give higher dispersion for the 3800 Å - 5200 Å region, but this gain in dispersion is accompanied by a loss in speed. Our fastest grating, the Wood (15,000 line/inch), has a dispersion of 5 Å/mm in this region. As Figure 3 implies, the Littrow matches or exceeds the 15,000 line/inch Wood grating's dispersion in the range from 3800 Å - 4200 Å. Despite these advantages, this prism instrument cannot now be engaged in planetary observations because of two outstanding problems -- slanting spectral lines and flare spotting. The more important problem is that of slanting spectral lines. At present, the spectral lines on the Littrow plates are tilted at such a large angle that tracings of these features might yield erroneous data. Flare spotting or selected darkening of the plates is caused by scattered



Body and base of spectrograph.



Close-up showing front pier, jack, and foot of steel base.

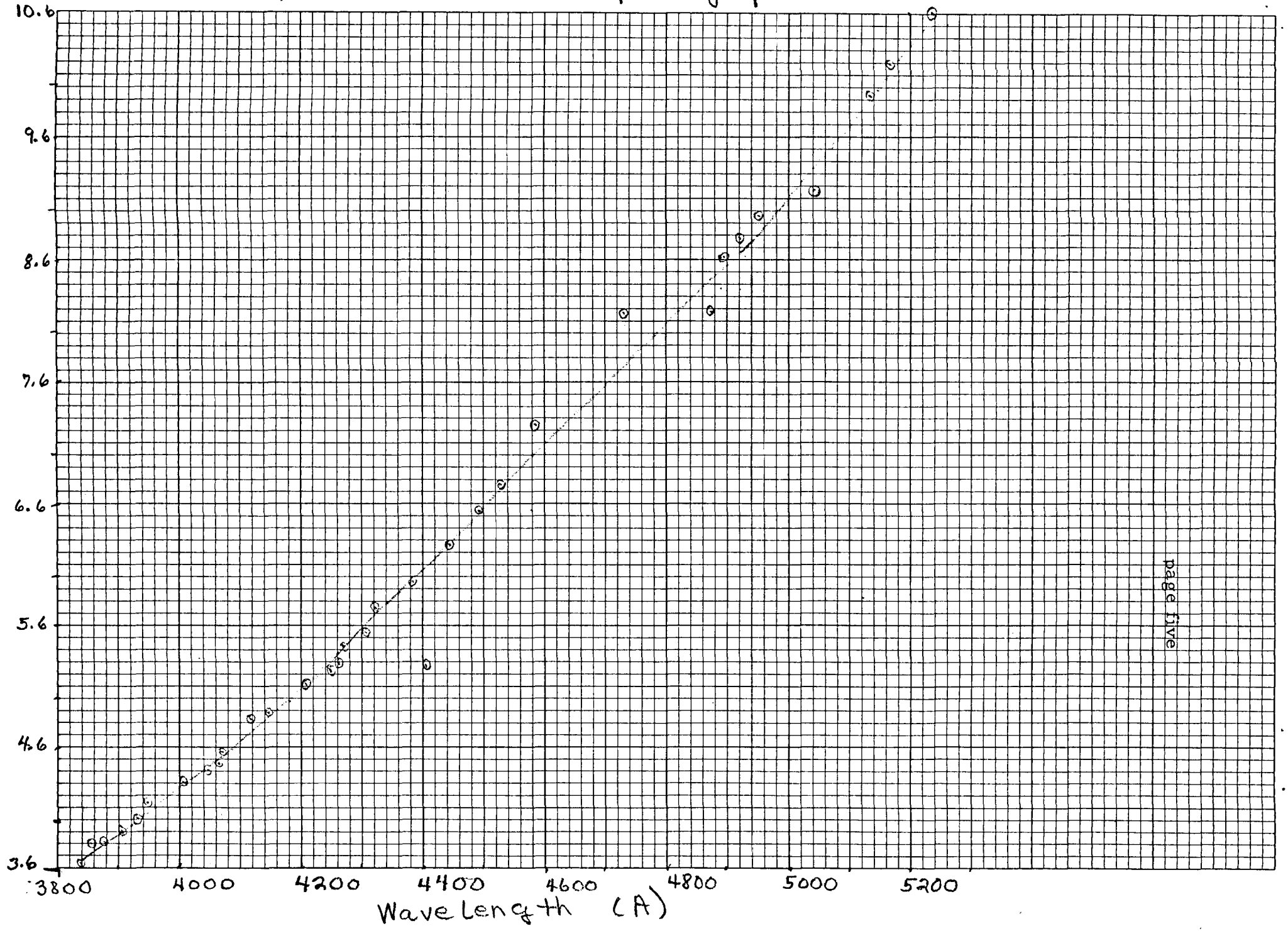


Lens - prism table. Prisms encased in metal holder.

Figure 2

Littrow Spectrograph

Figure 3 -- Graph of Wavelength (A) versus Dispersion (A/mm) for the N.B.S. Littrow Spectrograph -- 4300 A center



light within the instrument being brought to focus by the camera lens. Because we do not, as yet, have a light tight instrument, we cannot obtain unfogged solar spectra. This fogging has not yet appeared on our lunar plates, but it may show up on hazy nights.

After weighting the present disadvantages of the Littrow against the results of its preliminary tests, we decided to forego any further tests using Jupiter as a source; instead, we plan to concentrate on correcting our present problems. We believe that this approach will insure that the Littrow will be operational for the April 1967 opposition of Mars.

Area 2. Testing a New High Speed Emulsion.

In conjunction with our tests of the Littrow spectrograph, we evaluated a new "high speed" film whose characteristics indicated that it could be used to reduce our observing time for planetary spectra. This film, Kodak's Linagraph Shellburst, produces maximum contrast even though the subject contrast might be very low. It has high resolving power, medium granularity, and extremely high acutance (sharpness). In the range from 4000 Å - 7000 Å, this film is especially sensitive.

Another important feature of the Linagraph Shellburst Film is its Estar Gray Base. This polyethylene terephthalate base is highly stable to dimensional changes caused by humidity, temperature, processing, and aging.

Our tests of the Linagraph Shellburst Film with the moon and our spot sensitometer show that the film cannot be used for planetary work. The film is faster than a 103a O plate for short exposures but becomes slower and slower with longer exposure times. Since the Linagraph Shellburst Film is not fast enough for planetary work we shall employ various hypersensitization techniques to increase our plate speed in the 3800 Å - 5200 Å region.

Area 3. Remounting the Photoelectric Scanner.

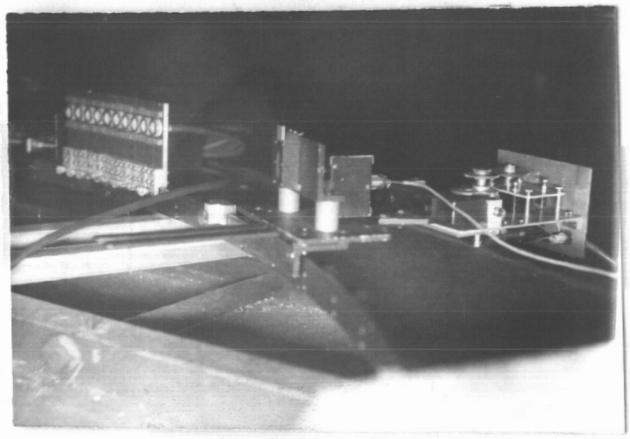
The photoelectric scanner described in Semi-Annual Status Reports No. 3 and No. 4 could not be used to scan the solar spectrum because the

little carriage containing the lead sulfide cell was too crude in construction for a smooth operation. A more elaborate arrangement was designed and its construction required almost a year because the work was done by an instrument maker who drew up the design and completed the job on his own time and in his own shop. The University's shop did not have the personnel or the equipment to do this work. Since the design for this new scanner involved modifications for research projects that will not contribute results to the purpose of this grant, the university paid the entire cost of this new mount.

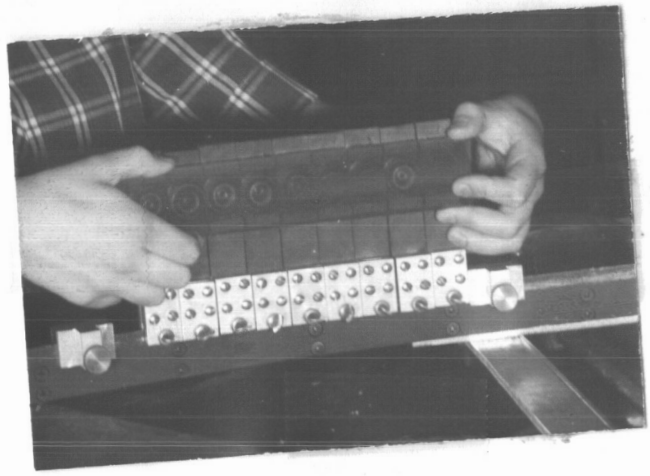
This new mount for the scanner permits easy interchangeability between the photographic and photoelectric components, it is particularly useful since we want to scan in the infrared (0.8 to 1.2 microns) and to photograph in the visible (0.7 to 0.4 microns). The combination, photo-electric scanner and photographic assembly which fit onto the Wadsworth pier, consists of a metal basepalte upon which has been mounted a segment of parabolic track a short distance in front of a second, semi-circular track. (Figure 4).

The shape of the parabolic track was determined by calculating the values of the focal plane distances for the Wadsworth parabolic curve. The classical equations derived in Sawyer's Experimental Spectroscopy were used to find a given position of the focal plane for the various orders of grating spectra. Because of this design procedure, a plate mounted on any section of this track should be nearly in focus. Set screws in the base-plate permit slight changes in the track shape so that a sharp focus can be obtained.

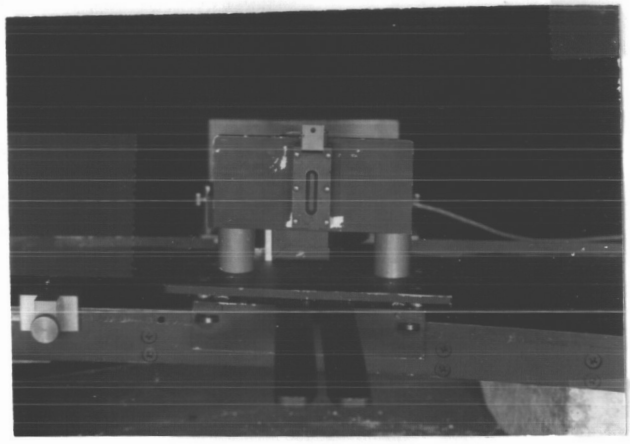
Plates are not directly attached to this parabolic track but rather to interconnecting metal-plastic uprights which can quickly be screwed onto any section of this track. When connected to a vacuum pump these uprights retain a sufficient vacuum to hold the plates firmly in place. These uprights can be completely removed from the parabolic track to give the scanning device a clear field of view.



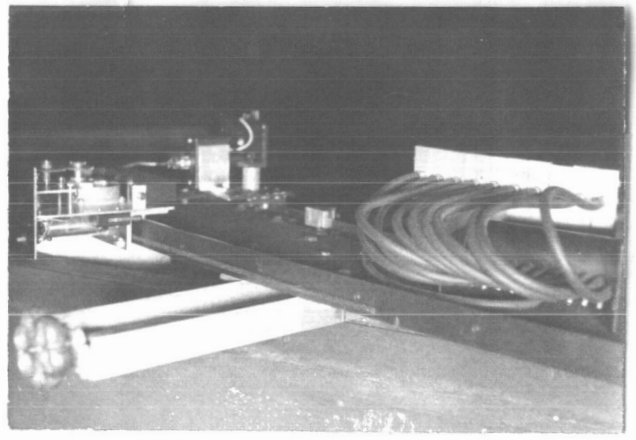
New mount showing both photographic uprights and detector platform. Note parabolic curve.



Plates being mounted on photographic uprights.



Detector platform.



Rear view of detector platform showing driving motor.

Figure 4

New Mounting for Photocell and Plates

The detector platform which also traverses this parabolic focal plane is driven by a motor which travels along the second semi-curcular track. This motor has been stepped down through a gear reduction of 720:1 in order to drive the detector platform slowly across the focal plane. Either a photomultiplier or lead sulfide cell can be placed on the detector platform.

The detector output signal which is modulated at 700 cps by a chopper at the entrance slit of the spectrograph is coupled from the detector through a solid-state preamplifier into a synchronous solid-state amplifier. In the amplifier, the A. C. signal is rectified and filtered before being applied to a potentiometer recorder.

Initial tests conducted with the photoelectric scanner indicate that the lead sulfide cell has deteriorated to such an extent that it is unusable. We are now in the process of ordering another cell for the scanner.

Area 4. Modifying the Vacuum Equipment.

In Semi-Annual Reports No. 6 and No. 7 we have discussed the main difficulties involved in the positive identification of nitrogen dioxide features. One of these difficulties, the fact that the spectrum of nitrogen dioxide is very complex and has not been analyzed in the visible region, has been alleviated somewhat by a recent paper by Douglas and Huber ("The Absorption Spectrum of NO_2 in the 3700 - 4600 Å Region", Canadian Journal of Physics, Vol. 43 (January 1965), pp. 74-81). In this paper Douglas and Huber have discussed four well-resolved bands in the 3700 - 4600 Å region; by rotational analysis, they determined the electronic transitions involved in producing these four bands.

We have attempted to obtain contact replicas of the $N^{14}O_2$ plates taken by Douglas and Huber but have been unable to do so. However, since our gratings give dispersions comparable to that of a 6000 lines/cm grating, we hope to be able to reproduce their results.

Before beginning a new study of the 3700 - 4600 Å region of the nitrogen dioxide spectra, we modified our vacuum system in order to:

1. obtain purer samples of nitrogen dioxide, 2. measure the partial pressures of nitrogen dioxide more accurately, and 3. change the path lengths of nitrogen dioxide in the optical cell with greater ease. These modifications are shown in the flip diagrams (Figures 5 and 6). All work was done under the guidance of Dr. Sebastian Karrer our consulting chemist.

In order to obtain purer samples of nitrogen dioxide, we removed the nitrogen dioxide cylinder from the system and built a new gas collecting system (Figure 7). With this new system we collect our sample of nitrogen dioxide by opening the the NO_2 cylinder and letting the gas bubble through the tubing until most of the residual air is expelled. Then, the stopcock to the partly evacuated gas collecting bottle is opened and the bottled filled with gas until atmospheric pressure is reached. When atmospheric pressure is reached, the bottle can easily be removed and the gas stored for future use or immediately injected into the vacuum system. Since this new gas transfer process takes place in a ventilated area outside the laboratory, the danger of contamination is reduced. Another advantage of this method is that the Tygon tubing which tends to absorb nitrogen dioxide does not remain on the system for an extensive period of time. This new process also permits the transfer of several types of gases (nitrogen dioxide, nitrous oxide, carbon dioxide, oxygen) from pressurized tanks to the vacuum system with the minimum of difficulty.

A second cold trap was added to the vacuum system in order to obtain purer nitrigen dioxide samples. This new cold trap is not only closer to the distilling section of the vacuum system but also can be removed more easily. Its double walled design enables the cold trap to freeze out the nitrogen dioxide more readily.

A glass-rubber tubing inlet was added to facilitate the addition of large quantities of dry nitrogen. The dry nitrogen tends to flush out the vacuum system and is a particularly good agent for removing water which tends to collect around the internal glass joints. Our earlier attempts to vaporize this residual water by heating were unsuccessful.

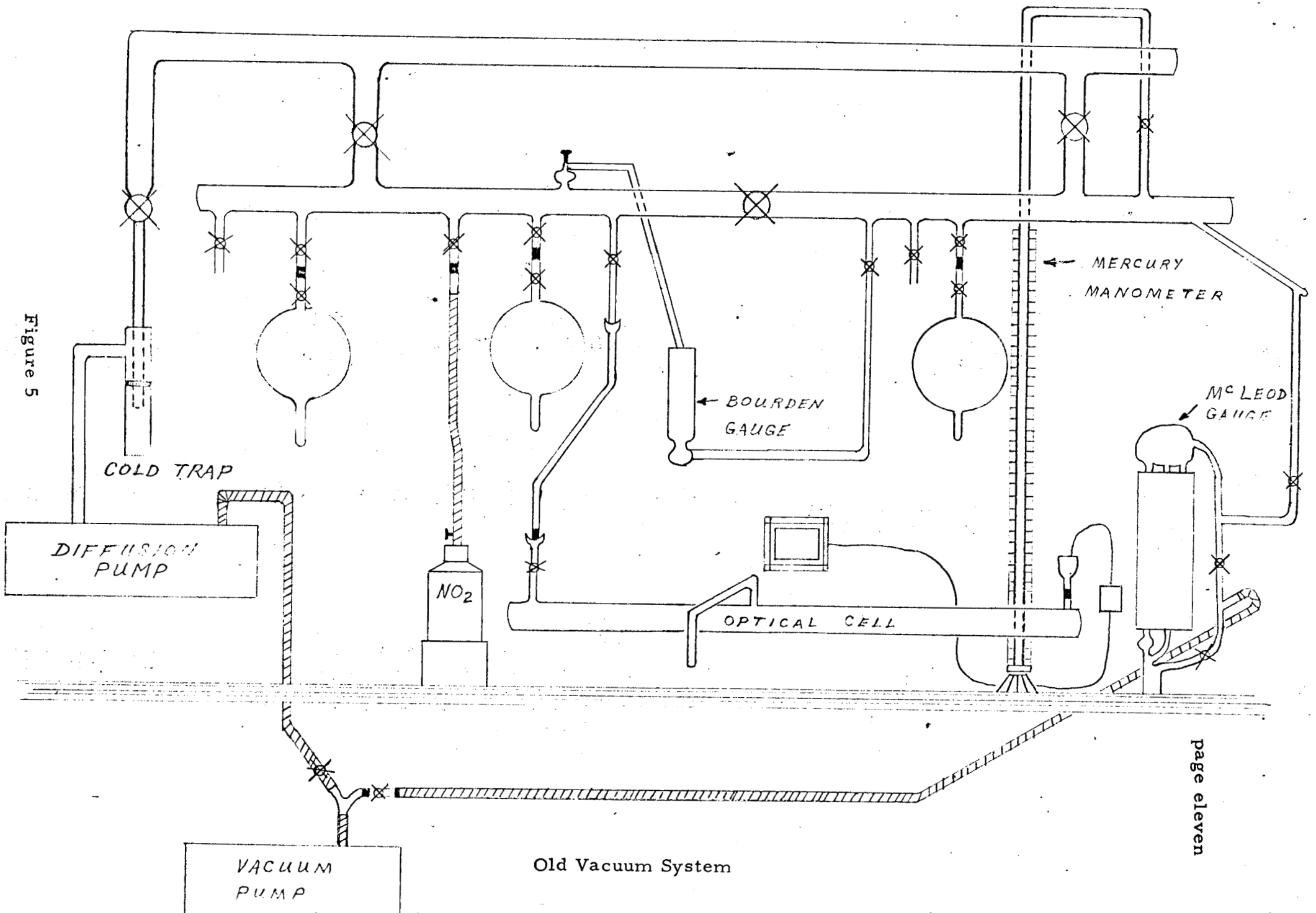


Figure 5

Old Vacuum System

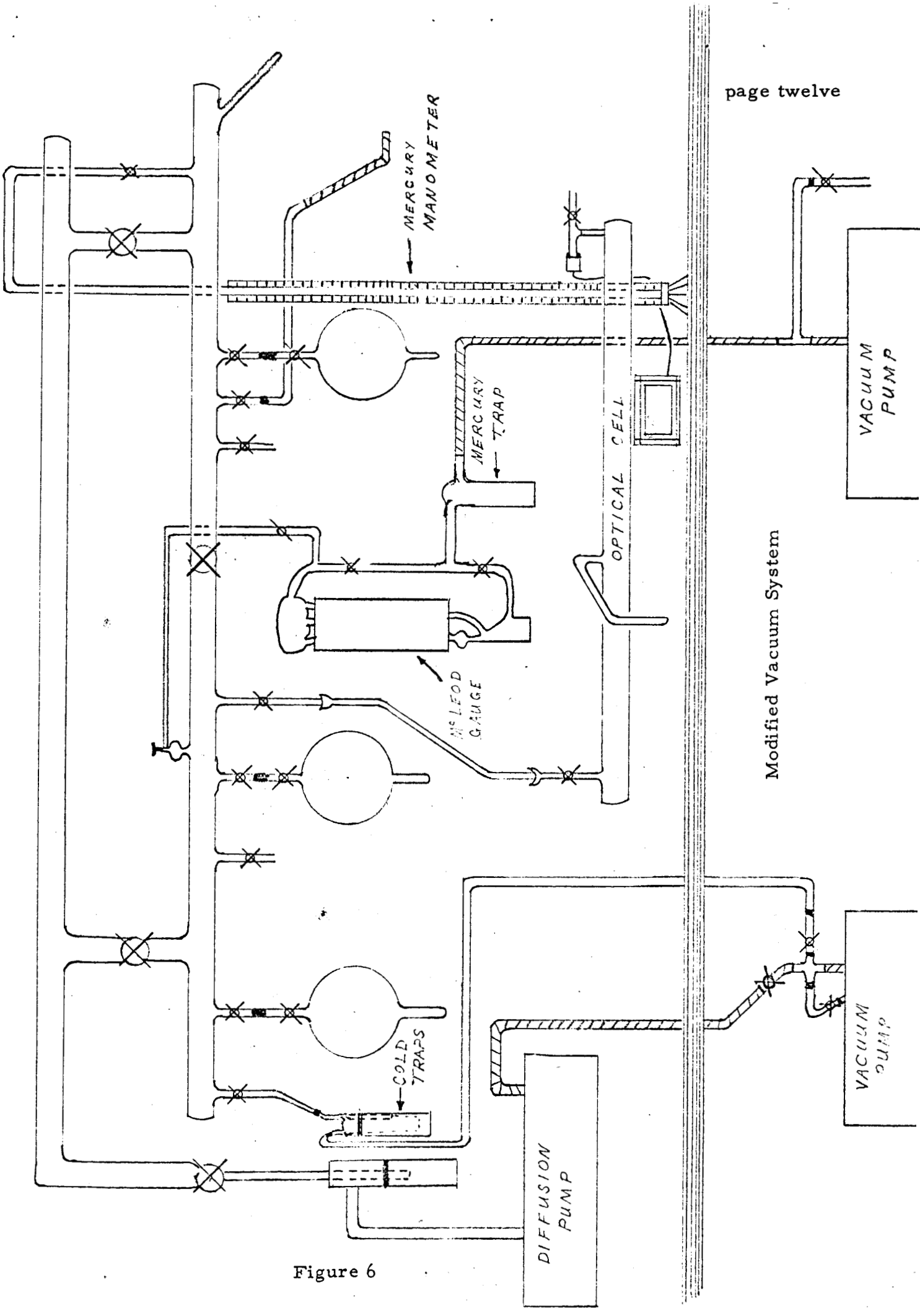
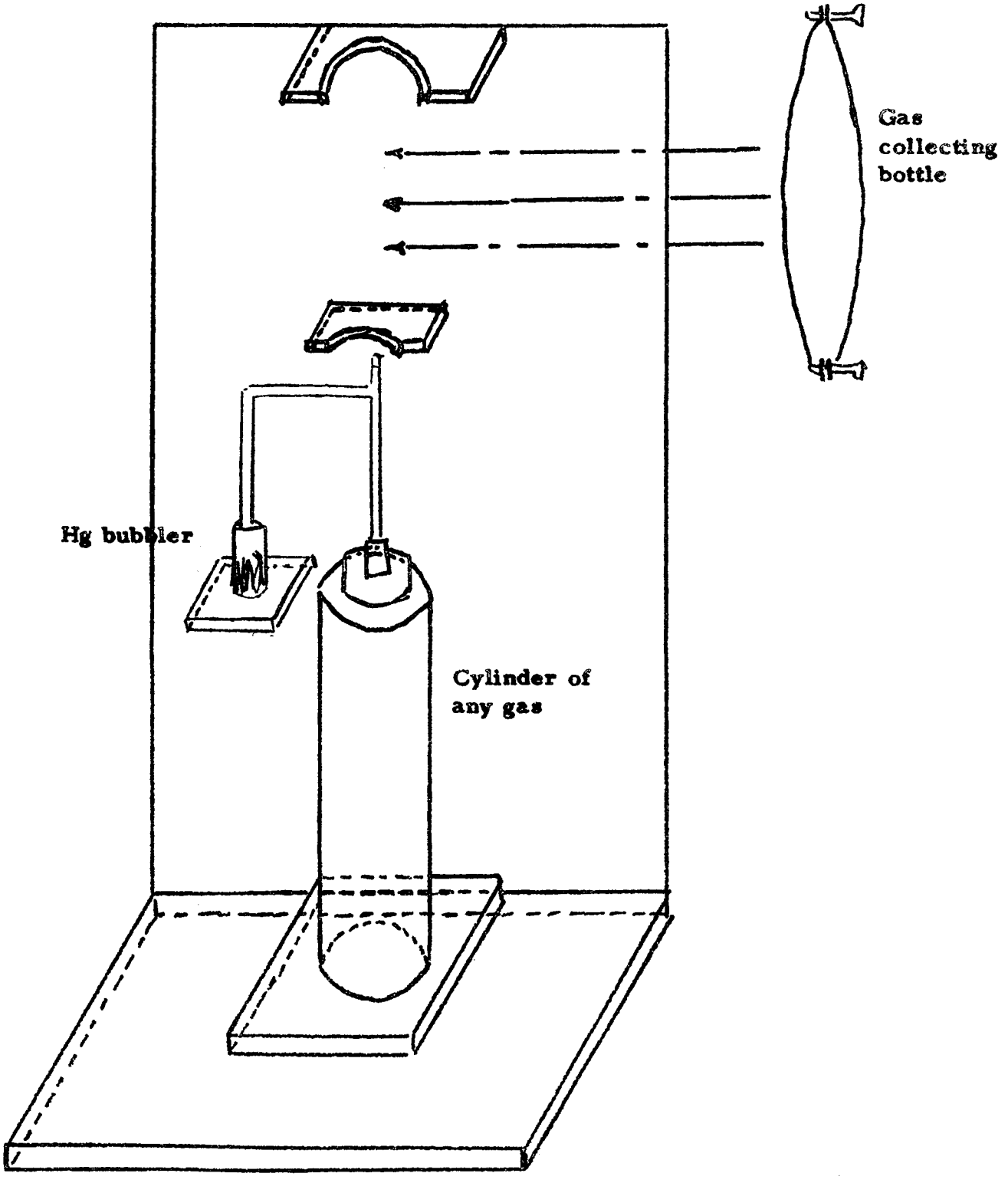

MERCURY MANOMETER
MERCURY TRAP
OPTICAL CELL
VACUUM PUMP
McLEOD GAUGE
COLD TRAPS
DIFFUSION PUMP
VACUUM PUMP
Modified Vacuum System

Figure 6



Gas Collecting System

Figure 7

After these modifications and a thorough cleaning of the flasks to be used in the distillations we plan to purify our nitrogen dioxide by the method outlined by Hall and Blacet "Separation of the Absorption Spectra of NO_2 and N_2O_4 in the Range of 2400 - 5000 Å", Journal of Chemical Physics, Vol. 11 (November 1952), pp. 1745-1749.

To obtain more accurate pressure readings, the Bourden Gauge was removed from the systen and the McLeod Gauge moved into the Gourden Gauge's old location. The surface coating on the small mirror in the Bourden Gauge had been corroded by the nitrogen dioxide, making this gauge unreadable. This gauge is now being repaired.

The McLeod Gauge was moved because its old location at the extremity of the system led to inaccurate measurements of the total vacuum system pressure. Before its re-location the McLeod Gauge was thoroughly cleaned; and the mercury filtered.

A second vacuum pump for evacuating the McLeod Gauge apart from the rest of the system was also added. Its use insures faster, more accurate measurements of system pressure and guarantees that no air can leak back into the system whenever a pressure reading is taken. A mercury trap was added in the gauge-to-pump line to prevent mercury from accidentally entering the new pump.

To aid us in changing the path lengths of the nitrogen dioxide in the optical cell, we added a second stopcock to the optical cell. By means of this stopcock, the optical cell could be filled with a gas without having to inject this gas into the entire vacuum system. Of course, pressure and hence pathlength changes can be performed by changing the temperature of the glass freeze-out finger.

Our work on the nitrogen dioxide spectra has been delayed because we have not been able to measure the temperature of the solid dinitrogen tetroxide in the glass freeze-out finger accurately. We cannot use glass

thermometers with our present set-up since we cannot totally immerse them in our low terperature baths and, hence, cannot get consistent temperature readings.

We are in the process of ordering a thermocouple unit from Leeds and Northrup Company. This unit will enable us to measure temperatures from -150 to + 150°C by means of a copper-constantan indicator. Temperature readings will be continuously recorded on a strip chart which has a step response time of 5 sec. These temperature readings will be accurate to within ± 2°C.

Area 5. Related Studies.

a. Correlation studies of Martian phenomenon.

This report showing a correlation between Martian clouds and Martian seasons was submitted by Mr. Alan Gillespie who had worked on it during the summer months. Errors in some of the data required that the paper be revised. Mr. Gillespie is doing this while continuing his studies in college. He will resubmit this paper this summer for possible publication.

b. Variation of NO_2 in the Earth's Atmosphere.

The Master's thesis to locate variations in the NO_2 content in the earth's atmosphere by examining spectra of the moon taken at different altitudes failed to show any evidence of telluric nitrogen dioxide around Washington. It is quite possible that this contaminant in the atmosphere can be detected only through a long path close to the ground. This result indicates that the NO_2 discovered on the 1956 and 1960 Martian spectra taken by Kiess at Georgetown was not of terrestrial origin. Mars was never observed close to the horizon.

c. Investigation of the Near Infrared Spectra of Nitrogen Dioxide and Mars.

In this investigation several plates of Mars taken during the 1956 opposition were used. Tracings of these plates in the 8662 - 8868 Å region were compared to tracings of the moon and to tracings of the nitrogen

dioxide spectra taken with the 7,500 line per inch Anderson grating at the National Bureau of Standards.

Our results were inconclusive since the Martian spectra were very faint and hypersensitization plus scratches on the plates caused spurious features in the tracings. We were able to locate several new nitrogen dioxide absorption features in the 8000 - 9000 Å region; but we have not published our results because incongruity in shapes of the bands indicates that some contaminant, probably water, may have been present in the saboratory sample of nitrogen dioxide. Near infrared absorption features have been reported by several investigators (Cury and Herzberg, "Extension of the Visible Absorption System of NO_2 to Longer Wave-lengths", Nature, Vol 131 (June, 1933), p. 842; and Pearse and Gaydon, The Identification of Molecular Spectra 3rd ed, New York: John Wiley and Sons Inc., 1963) but no information as to their exact location has been published. In view of the many Martian features reported in this region, we think it would be useful to repeat this study of nitrogen dioxide using purer samples and higher dispersion.

d. Owen Paper.

Owen's search for nitrogen dioxide in the Martian atmosphere ("The Composition and Surface Pressure of the Martian Atmosphere: Results from the 1965 Opposition," Astrophysical Journal, Vol 146 (October, 1966), pp. 257-270) is inconclusive for two reasons: 1. He does not have a comparison spectrum for his plate centered at 4500 Å and 2. His tracings of Mars do not show an intensity calibration scale.

Sinton, et al., ("Mars: The Origin of the 3.58 and 3.69 - Micron Minima in the Infrared Spectra," Science, Vol 147 (January 13, 1965), pp. 1286-88) and Heyden, et al., ("Faint Terrestrial Lines in the Solar Spectrum Near 8200 Å," Astrophysical Journal, Vol 143 (1966), pp. 595-97) have demonstrated the importance of a comparison spectrum in distinguishing between planetary and telluric features on planetary plates. When taking Martian spectra, there is an additional reason for including a comparison.

As the 1956 spectrograms of Kiess and Corliss reveal ("High Dispersion Spectra of Mars," Astrophysical Journal, Vol 126 (1957), pp. 579-84), there is a striking decline in the Martian spectral intensity from 5700 - 4500 Å relative to the spectral intensity of the moon. These results are corroborated by the many studies of Martian monochromatic albedos which reveal that the albedo declines with decreasing wavelength. Therefore, if a Martian spectrum, especially a spectrum centered near 4500 Å, is not matched in density with the higher wavelength section of a comparison spectrum the planetary spectrum will probably be overexposed.

Our laboratory studies of the spectrum of nitrogen dioxide show that overexposure can completely wash out a NO_2 absorption feature. Owen's single plate centered at 4500 Å may not show an NO_2 feature at 4480 Å because this feature is washed out by overexposure.

Another difficulty with Owen's work involves the intercomparison of Owen's tracing of Mars with Marshall's tracing of the solar spectrum as absorbed by 0.125 mm-atm. of NO_2 ("Improved Test for NO_2 on Mars," Communications of the Lunar and Planetary Lab, Vol 2 (1964), pp. 167-173). Since Owen's densitometer tracings are not accompanied by an intensity scale and only one of Marshall's tracings of 0.125 mm-atm of nitrogen dioxide has an intensity calibration, a quantitative analysis cannot be made. A qualitative check of the enhancement of the solar and planetary features by nitrogen dioxide is not possible since Marshall does not include a tracing of his solar comparator in the 4882 Å region and Owen does not have any comparator. Because of this lack of intensity scales and solar comparators, any judgement as to the presence or absence of a nitrogen dioxide feature on Owen's plate is doubtful.

Personnel on Grant.

Dr. Francis J. Heyden, S. J., Research Director

Dr. Carl C. Kiess, Assistant Scientific Director

Dr. Sebastian Karrer, Consultant

Dr. Whiting R. Willauer, Project Head

Graduate Student Assistants.

Miss June LoGuirato

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Mr. Richard Munis

Fr. James E. O'Brien, S. J.

Financial Report.

C.f. University Nonprofit Institutional Management Report (forwarded by the University Treasurer's Office).